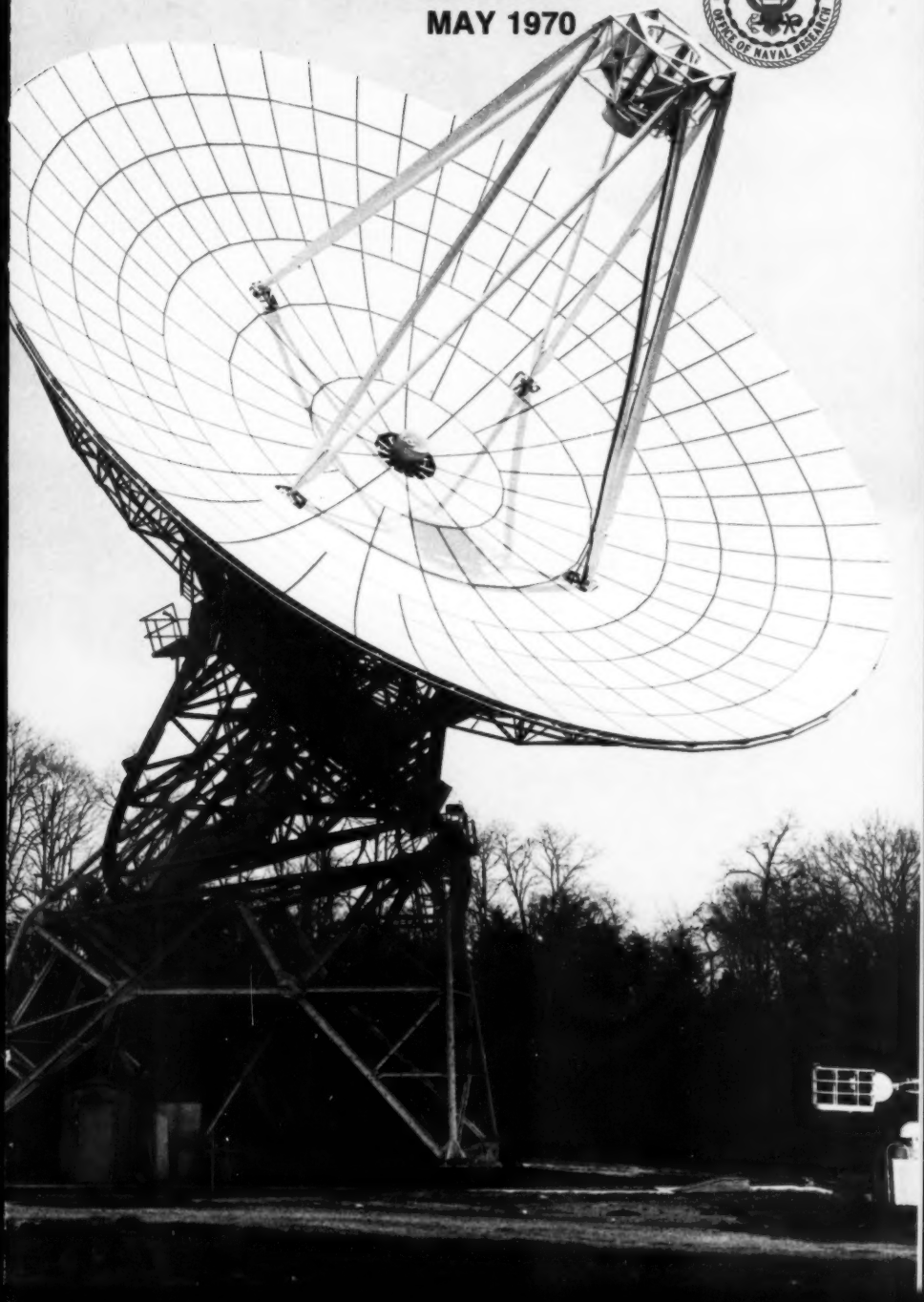
NAVAL RESEARCH

REVIEWS

MAY 1970



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Portraits in Science

TOP NEWS IN THE SCIENTIFIC COMMUNITY WAS THE ELECTION OF DR. MINA S. REES TO THE PRESIDENCY OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (AAAS) FOR THE YEAR 1971. CURRENTLY DEAN OF THE GRADUATE DIVISION OF THE CITY UNIVERSITY OF NEW YORK, DR. REES IS WIDELY KNOWN FOR HER SERVICE ON MANY SCIENTIFIC AND EDUCATIONAL COMMITTEES AND PANELS, AND IS WELL REMEMBERED FOR HER SIX YEARS AT ONR. AS THE DIRECTOR OF THE MATHEMATICAL SCIENCES DIVISION FORM 1947 TO 1953. SHE WAS LARGELY RESPONSIBLE FOR THE COMPUTER SCIENCE PROGRAM IN ONR, AND, THE WHIRLWIND PROJECT AT MIT. WHIRLWIND WAS A PIONEER OF THE LARGE-SCALE, HIGH-SPEED COMPUTING SYSTEMS WITH PARALLEL ACCESS MEMORY AND MULTIPLE INPUTS.

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Hypnosis

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The Navy and Marine Corps are constantly looking for ways to increase the ability of their personnel to withstand the wide variety of stresses to which they are subjected. Fatigue, extremes of heat and cold, motion sickness, isolation, hostile interrogation, and pain are examples. Hypnosis has often been suggested as a useful means for increasing resistance to such stressors. Dr. Martin Orne, author of this article, is recognized internationally as an authority in the experimental study of hypnosis. The article reports his progress under Office of Naval Research sponsorship towards achieving an understanding of the basic nature of hypnotic phenomena, a necessary first step towards the rigorous study of the utility of hypnosis in enhancing performance in Navy and Marine Corps settings.

The mystic, the magical, the supernatural have in the past been closely associated with the hypnotic phenomenon. Even to this day there is a tendency for individuals to be for or against it, to believe that it is a panacea or to reject it as something akin to fraud. While the phenomenon was already known to the Egyptians and was discussed in the Elba Papyrus, it was in large part rediscovered and attracted wide attention with Mesmer, after which it was described almost completely by one of his students, the Marquis de Puysegur.

The problems which have made an objective understanding of the phenomenon difficult were already clearly evident when Benjamin Franklin, as chairman of a commission established by Louis XVI, wrote a report investigating Mesmer. While acknowledging that dramatic events could and would occur with mesmerized patients, the commission brough back the finding that no magnetic fluid was required to account for these changes – indeed, that they were merely the product of imagination. This view is remarkably close to that based on modern investigations. The major disagreement would be about the word "merely"; in other words, the modern investigator has developed a healthy respect for and some understanding of the power of human imagination and its variants.

In view of the many implications that hypnosis and related phenomena may have for the mental capabilities of an individual, an understanding of hypnosis is relevant to any systematic effort to comprehend what we call personality, motivation, memory, and thinking. Furthermore, hypnosis has been proposed as a technique to modify human capabilities,

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and some of these changes can have special relevance for the Navy. Not only has hypnosis been suggested as a means of increasing an individual's capability of adequately functioning in the face of acute or chronic stress, of increasing his memory, visual and auditory acuity, vigilance, learning ability, and motivation, but also its use has been suggested for certain special purposes. *The Manchurian Candidate* fictionally dramatized the possibility that posthypnotic suggestion might be employed to control an individual's behavior without his own awareness and to compel him to carry out desired actions, potentially making him an unwitting tool of a foreign power. Similarly it has been proposed that posthypnotic amnesia might be induced for sensitive information in individuals subject to capture, such as downed Naval aviators, a technique that, superficially at least, seems interesting. Though the information would not be available to the individual consciously, it would be readily available when a pre-arranged signal was given to lift amnesia. In a similar way, hypnotic techniques have been advocated as ways of controlling and modifying an opponent's thoughts and actions and have been implicated in brain washing.

It is not necessary to belabor the offtimes ingenious and thought-provoking suggested applications of hypnosis. It will be immediately clear to the reader why a phenomenon which makes it possible to alter an individual's memory for events of the past, to induce new attitudes about the past, present, and future, and to compel him to carry out a wide variety of behaviors at some future time in response to a predetermined cue, should act as a fertile stimulus to the imagination. The basic research carried out in our laboratory, first at Harvard and more recently at the University of Pennsylvania, has been directed towards clarifying a variety of basic questions about how, when, and why these events can occur. It was first necessary to develop techniques for doing systematic research on this problem before even beginning to answer questions about the feasibility of the many concrete proposals that had been put forth for the utilization of hypnosis.

What Characterizes Hypnosis?

While Mesmer is appropriately credited with reviving the interest in hypnosis in modern times, his patients were mesmerized without the kind of verbal suggestions one usually associates with hypnosis today. Instead they invariably entered the state by what he termed a "crisis," which can best be described in modern terms as a "hysteric seizure." The patients then went to sleep and awoke minutes to hours later, usually with relief of their symptoms. Certainly this sequence of events is vastly different from hypnosis as it is known today; similarly hypnosis as we know it differs markedly from hypnosis as described by

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Charcot—who claimed that when the top of a subject's head was rubbed he would pass from sleep to somnambulism—and from the phenomenon evoked by Emile Coue under the heading of self-hypnosis.

The behavior characteristic of the hypnotized individual seemed to vary so widely from place to place and from time to time that some explanation was necessary. To account for such differences we hypothesized that the hypnotized subject behaves as he does either because it is suggested to him that he do so or, in the absence of any suggestion, because he believes certain behaviors to be typical of the hypnotized individual.

In order to test the hypothesis experimentally, we had to invent as a variable as plausible "characteristic" of hypnosis that had, however, never been observed previously—we chose catalepsy of the dominant hand. Catalepsy—waxen rigidity of the limbs—is a common occurrence during hypnosis, but when it occurs it happens in all extremities, the trunk, the head, and so forth. It had never been known to occur in one part of the body while the rest remained flaccid. Catalepsy of the dominant hand was chosen because it sounded "scientific" and would thereby be plausible to students, reminding the college undergraduates of lectures about stuttering due to suppressed left-handedness, *etc.* A lecture about hypnosis was then arranged for a large class of college students. This included a demonstration with three subjects chosen from the class who, unbeknownst to the group, had previously been hypnotized and given the suggestion that they would subsequently develop catalepsy of the dominant hand. The classic hypnotic phenomena were then demonstrated, including amnesia, age regression, and posthypnotic behavior. During the induction process catalepsy was carefully tested, and the hypnotist casually commented upon how typical the behavior of the subjects was concerning their catalepsy of the dominant hand (two subjects were right-handed and one was left-handed). In all other respects the lecture was accurate. A matched class of students received the identical lecture and identical demonstration but catalepsy was not tested.

A month later subjects from both classes were asked to volunteer for some experiments. They were brought to the laboratory and hypnotized. We observed the spontaneous development of catalepsy of the dominant hand in most of the subjects who had been at the appropriate lecture. No such phenomenon was observed, of course, among the control subjects, who had not seen the demonstration of dominant hand catalepsy.

The rather simple experiment characterizes the problems encountered in investigating hypnosis. It would seem that we are dealing with something that has the qualities of a chameleon. The hypnotized subject will manifest whatever behavior he believes characteristic of hypnosis; furthermore, he may be taught to do this without either his own or the

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hypnotist's awareness. As a result, two hypnotists with varying convictions can go forth (attempting to test their beliefs) and will observe diametrically opposite findings, though both are applying apparently objective procedures. It is not surprising therefore that the history of hypnosis is characterized by acrimonious disputes and that many distinguished investigators became disappointed and left this field of inquiry.

The Development of Special Research Techniques

It became crucial to develop ways of recognizing the difference between those aspects which are essential characteristics of hypnosis and those which might just as easily be epiphenomenal artifacts subtly suggested to the individual. The problem here was analogous to that encountered in the evaluation of drugs with psychic effects. It is not enough to know that aspirin relieves a headache since an inert pill, or placebo as it is called, can under appropriate circumstances do equally well. Even a placebo, however, is not adequate to evaluate a new medication, since the doctor who is aware of what he is administering would be enthusiastic, interested, concerned, and solicitous of side effects when administering a new medication but rather disinterested or even bored when giving a placebo. It is for these reasons that psychopharmacologists evolved the double-blind technique as a partial solution to some of these difficulties.

Studies utilizing hypnosis suffered from similar problems. Not only would hypnotized subjects manifest the behavior congruent with the hypnotist's expectations but there was an additional difficulty. When the hypnotist gave suggestions to the hypnotized individual, they were characteristically delivered with enthusiasm and conviction; on the other hand, during the control trials with the same subject in the waking state, suggestions were presented in a more routine, matter-of-fact fashion. Thus, even though a control procedure was employed, the results were not necessarily conclusive, for the subject could easily realize that he was expected to do better in hypnosis. Furthermore, the instructions were inadvertently being given in a manner to insure that the subject would try harder while hypnotized.

To circumvent these difficulties, it was essential to develop a technique which would guarantee that the hypnotist would treat the unhypnotized subject in the fashion as the hypnotized. He would have to provide the same kinds of information about what he expected the subject to do and do it in the manner usually employed for the hypnotized person, but without the subject's actually entering hypnosis.

The ability to enter hypnosis varies with individuals and, while most, cooperative subjects are able to enter hypnosis, five to ten percent find it impossible to do so despite repeated attempts with competent hypnotists. If one eliminates those who appear negativistic and who are

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not really cooperating, one has a group who are exceedingly unlikely to enter hypnosis, a counterpart to the ten to twenty percent on the other end of the continuum who are capable of entering very deep hypnosis quickly and easily. These latter individuals are the ones who readily show all the classic phenomena of deep hypnosis, while the former do not seem to be able to do so. This appears to be an individual difference in subjects, not easily related to intelligence, independence, thought, leadership potential, and so forth. Nor does there seem to be a simple relationship to the usual kind of personality dimensions studied by psychological tests among the normal population. Yet within each individual, the ability to respond to hypnosis is relatively stable over time and largely independent of the hypnotist or the situation, so that it can be considered as a constant for experimental study. Furthermore, given repeated exposure to hypnotic induction, both highly hypnotizable and low hypnotizable subjects develop the same general knowledge about the phenomenon and about the laboratory's purposes and aims: since they are drawn from the same populations, they have similar background information available to them.

The simplest approach, then, to the experimental design problem in hypnosis research, seemed to be to ask subjects to simulate—to make believe that they were actually hypnotized. There were many statements in the literature indicating that subjects were unable to carry out such instructions, that simulation was easily recognized by competent hypnotists. Our early efforts in this regard bore out this assertion. Subjects typically tried to simulate but performed extremely awkwardly. Their behavior was transparent and usually interspersed with sly smiles, surreptitious glances at the hypnotist and similar cues which permitted even the most unskilled hypnotist to recognize a fraudulent performance.

In discussing the experience with subjects it became clear why they found the task so difficult. They were aware that the hypnotist knew they were simulating and they felt they had been presented with a task they viewed as impossible. Regardless of their performance, there would be no way in which they could "win." To cope with this problem, the situation was altered slightly but highly significantly. Subjects unable to enter hypnosis were instructed by a colleague as follows:

"In the past you have tried to enter hypnosis and I realize that you have been unable to do so. Today we want you to take part in a particularly important experiment. You will be working with Dr. X, who has never met you and your task will be to go in and fool him, to convince him that you are a good hypnotic subject and able to enter deep hypnosis. Dr. X will know that some people will be trying to fool him by simulating hypnosis but he will not know who. If he catches on to the fact that you are simulating he will stop the experiment immediately; so, even if you don't know how you are doing, don't think you have given yourself away. You haven't because if you do Dr. X will stop the experiment. I

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can't tell you what to do or how to behave. Do the best you can. I know it is a difficult task but we have found in the past that intelligent subjects have been able to do it successfully. Good luck!"

Subjects instructed in this fashion were randomly mixed with subjects who were in fact extremely good hypnotic subjects and both were seen by a hypnotist who was in fact blind as to the subjects' true status.

When this line of inquiry was first undertaken, we felt it might provide a useful control technique but still expected that a highly trained hypnotist would be able to distinguish readily between these two groups. To our amazement we found that this was not the case. A number of simple tests which we and our colleagues traditionally employed in evaluating hypnosis proved to be inadequate to the task of discriminating between hypnotized and simulating individuals. These included the use of moderately painful stimuli such as pinching, pinpricks, or faradic shock to the fingers. In careful studies using motion pictures and videotape, observation of the eyes, face, posture, general coordination, speech, tests of endurance, and so forth, not only were colleagues within the laboratory unsuccessful in discriminating between these groups, but investigators from elsewhere who had worked with hypnosis extensively found that the diagnostic criteria they had believed to be infallible failed to discriminate.

This did not mean that we found no differences. The experiences of these two groups were radically different, the attitudes toward the experiment once it was over were radically different, *etc.* It did mean, however, that many of the behaviors commonly attributed to hypnosis could as readily be explained as a function of subtle cues and expectations on the part of the hypnotist, communicated without his awareness, rather than as due to the presence of the phenomenon itself.

We had developed a technique by which we could indeed evaluate the extent to which a particular phenomenon could be ascribed to the chameleon-like quality of hypnosis and the extent to which it could be viewed as an essential characteristic. The fact that hypnosis could be simulated successfully did not, of course, imply that there is no such phenomenon, any more than the fact that a psychologist had successfully simulated schizophrenia and fooled the personnel in a leading psychiatric hospital would imply that schizophrenia is therefore nonexistent. Far from questioning the reality of hypnosis we had established a rigorous criterion by which to appraise its intrinsic properties. The simulating control group allowed us to begin the difficult task of evaluating the many claims concerning the unique properties of hypnosis and the powers it confers upon the hypnotized subject. It would now be possible to discriminate between those aspects of the behavior of the hypnotized individual that are of necessity a function of being hypnotized and which might as easily be explained in other ways.

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Examples of Research Problems

A number of problems could now be examined. For example, it was possible to establish that the physical capacity of the deeply hypnotized could be matched by that of simulating subjects. These subjects not only were able to maintain their limbs in uncomfortable positions for long periods, support heavy weights, pull on a dynograph, *etc.*, at levels of performance greater than we had anticipated, but they could also duplicate the "experiment" commonly demonstrated by stage magicians—staying in a totally rigid position supported only by their neck and heels between two chairs while carrying the weight of another person on their abdomen. It became clear that this and similar feats of strength are within the repertoire of the normal waking individual provided he is appropriately motivated; it merely had not occurred to anyone that this might be a possibility.

Another set of studies (1) considered the question of whether deeply hypnotized subjects could be compelled to carry out antisocial, destructive actions. Rowland (2) and subsequently Young (3) had both shown that deeply hypnotized individuals could be compelled to pick up a poisonous snake with their bare hands, to remove a penny with their bare fingers while it was dissolving in a dish of concentrated nitric acid, and to take this acid and throw it at a research assistant. These actions are clearly self-destructive and antisocial. When these same subjects were asked in the waking state whether they would carry out these actions, they appeared horrified at the mere thought. The Young study was then carefully replicated with the addition of the simulating control procedure. It was indeed true, as Young had reported, that five out of six deeply hypnotized subjects could be complled to carry out the items of obviously self-destructive and antisocial behavior and would, in the waking state, deny such a possibility. However, six out of six simulating subjects did likewise.

This study did not, of course, resolve the question of whether subjects would or would not carry out antisocial behavior under hypnosis but rather clarified some of the limitations of experimental work in this field. It showed than an independent control group is essential and that one cannot rely upon a subject's report about what he might do when asked in a different setting. Furthermore, the study helped establish the unique characteristics of the experimental situation and emphasized the extent to which nonhypnotized subjects would comply with the demands of the experimenter simply because he is an experimenter, a finding that had implications for many other research problems.

The same methodological approach was used in our studies of age regression, where we found that simulating subjects were able to reproduce the kind of findings that had previously been assumed to require deep hypnosis. Again, in a different context, we found it was possible

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for waking and simulating subjects to produce a wide range of physiological alterations at will—a capability that in the past was felt to require the presence of hypnosis.

The Meaning of Our Findings

Our studies using the real-simulating technique to study hypnosis clarified the many previous observations where hypnosis seemed to allow the subject to transcend his own capabilities. For the most part, they demonstrated that miraculous performances are within the repertoire of normal waking individuals. Since neither the subject nor the experimenter would have believed this to be the case, the subject's waking capabilities would have been grossly underestimated, had the experimenter not been truly blind as to the status of the subject and the subject not been truly motivated to maintain his role. Some of the most important observations to come from this technique, therefore, have dealt with previously unrecognized human capacities.

To date we have been unable to demonstrate clear evidence that the hypnotized individual is able to perform behaviors outside of the waking individual's capabilities. This in no way denies the dramatic reality of the hypnotic phenomenon. When the deeply hypnotized individual reports an hallucination, it is likely that he tells of what is subjectively real to him. When he eats an hallucinated meal, he may enjoy his repast and respond physiologically by a change in gastric and urinary pH as though he had indeed eaten the hallucinated meal. The unhypnotized subject, knowingly imagining such a meal, does not tend to feel satisfied by it nor does he seem to derive the same enjoyment from it; however, his imagining will also evoke changes in urinary and gastric pH (4). The difference between the hallucinating and imagining appears to reside more in the subjective experience than in objective performance.

Subjective reports, however, have not been the only source of demonstrated differences between simulating and hypnotized individuals. The first such difference we were able to objectively show, involved suggesting an hallucination for a person actually in the room. Let's assume that Dr. Jones is actually sitting to the left of the hypnotist and observing the experiment. The hypnotist then suggests to the subject that Dr. Jones is sitting in a chair (actually empty) on his right. Care is taken to induce this hallucination effectively and the subject is encouraged to interact with the hallucinated Dr. Jones. Provided he is deeply hypnotized, he will talk to him, shake hands with him, and so forth. After a while the hypnotist points to his left where Dr. Jones is actually sitting and asks, "Who is this?" Simulating subjects characteristically report, "I don't know," "Mr. Smith," or they may deny that they see anyone. When, at the conclusion of the experiment, they are asked why they had reported in this fashion to the real Dr. Jones, they very logically point out that

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since the hypnotist had told them to see Dr. Jones on his right and they had done so, he certainly could not be sitting on the hypnotist's left and they reasoned the correct response would be to deny his existence. In contrast, the deeply hypnotized individual will look at Dr. Jones, register surprise and do a "double-take," look back at his hallucination and then back to Dr. Jones. With some surprise he will recognize Dr. Jones where he is actually sitting and then say, "There are two of them!" The fact that an hallucination has been induced for Dr. Jones does not prevent the veridical perception of Dr. Jones, as no suggestion to do so has been given. Furthermore, the deeply hypnotized individual appears able to tolerate the incongruity of this situation and manifests what I have called "trance logic," ignoring the fact that one person can be in only one place at one time (5). That this phenomenon, which can, of course, be seen only in deeply hypnotized individuals, is not a function of previous knowledge or subtle cueing by the hypnotist is demonstrated by the fact that it is not manifested by simulators.

We have observed other differences between these two types of subjects that help clarify the nature of hypnosis. In a series of studies on posthypnotic behavior (6,7) we explored the occurrence of the posthypnotic response in the absence of the hypnotist outside of the experimental setting. We found that simulating subjects would respond more reliably and for a longer period to a posthypnotic cue in the presence of the hypnotist but would stop responding in a situation which they perceived to be outside of the experimental context. Deeply hypnotized subjects, however, were as likely to respond in the hypnotist's absence as in his presence.

In another study (8,9) we asked the question, "What would happen if the hypnotist disappeared while the subject was in deep hypnosis?" Using a tape-recorded hypnotic induction procedure with highly trained subjects, we arranged a "power failure." The tape-recorder came to a grinding halt, all lights extinguished, and the polygraph which was used to record subjects' physiological responses stopped. After a very brief attempt to restart the tape-recorder by flickering the switch, the technician muttered, "The fuse is out again," adding an appropriate pithy comment, and left the room. Observing the subject without his awareness once he was alone, we noted that deeply hypnotized subjects continued in the state for some period of time, apparently pulling themselves out of hypnosis after a period of some minutes had elapsed. Usually they would awaken and appear disoriented. On the other hand, simulating subjects characteristically opened their eyes and began to look as soon as they believed themselves to be alone.

It is clear from these and similar studies that, despite the superficial similarities which make it difficult to distinguish between the hypnotized subject and the simulator by simple observations, there is a vast difference between subjects who are hypnotized and those who are simulating.

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With appropriate techniques, these differences become evident and help clarify the nature of the changes, other than those of subjective experience, that are associated with entering hypnosis.

Conclusion

When a series of methodological tools which made possible the scientific study of hypnosis had been developed, it became clear that few of the previously reported findings could be accepted at face value. The motivated experimental subject has a repertoire of responses and capabilities far greater than heretofore recognized, and the methodological problems raised by this discovery have had considerable impact on much psychological research. At the same time, it became clear that hypnosis does produce profound alterations in the subjective experience of individuals and in some of their behavioral responses as well. With improved methods it has become imperative to reexplore many of the psychophysiological consequences of hypnosis. We have been able to show that there are differences in the hypnotized individual's response to pain (10) and it would seem surprising indeed if these differences were not accompanied by physiological differences—though they yet remain to be established. Again, while changes in the electroencephlograph, for example, have not been observed to date, newer techniques both in the analysis of EEG and in methodology of hypnotic research make further work essential.

Meaningful application of hypnosis for any purpose is not possible without first recognizing its nature. Our studies have not only allowed us to dismiss some of the quasi-magical ideas about hypnosis but have also evolved some hard criteria for the phenomenon. In the process of answering substative questions about human capability under hypnosis, we also inevitably are required to study more about human capabilities in the normal waking state. While we expect a great deal from the former, some of the most startling observations to date have been of the latter. Nonetheless, hypnosis remains a powerful, dramatic way of altering the subjective experience of the individual. An understanding of this process must ultimately increase our ability to predict and control human behavior.

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Frozen Red Blood Cells and Post-Transfusion Hepatitis

The transfusion of washed frozen red blood cells resuspended in albumin minimizes the hazard of post-transfusion hepatitis. The validity of this observation has been substantiated by statistical evaluation of studies on the incidence of inflammation of the liver after transfusion of frozen blood cells processed by a method used by Dr. J. L. Tullis at the Naval Blood Research Laboratory, Chelsea, Massachusetts. In these studies, resuspension of frozen cells in albumin did not result in hepatitis among 113 patients who received a total of 598 units of blood for an average of 5 units to individual recipients. Conversely, 4 patients who received frozen cells resuspended in the donors' plasma developed clinical and histologic evidence of hepatitis. Recipients of the cells in the plasma suspension numbered 118 who received 489 units for an average of 4 units per patient.

Gulf of Mexico Oil Spill

The Coastal Studies Institute (CSI) of Louisiana State University, a major contractor of ONR's Geography Programs, was called upon in March 1970 by the U.S. Coast Guard to provide data on currents in the vicinity of Breton Island, Louisiana. It was anticipated that when fires on the nearby Chevron well platform were extinguished, a large-scale oil spillage would begin. The Coast Guard was concerned to know how the oil would spread. Prior to attempts to quell the fire, a CSI team began a series of observations on currents, salinity profiles and temperature. Tide and wave data were recorded by instruments suspended from a nearby well platform. Surveillance and photographic coverage was made possible through use of Coast Guard helicopter flights. On the basis of data they were obtaining and their previous knowledge of nearshore water circulation, the CSI team was able to assist the Coast Guard in combating and monitoring the oil slick. The CSI also benefited by obtaining considerable new insight into water movements and the behavior of interfacing unlike water masses.

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Research on Metallic Base Composites

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Composite materials have multiple properties that make them attractive to the Navy for use in structural and nonstructural applications. Composites exhibit a combination of properties which are not possible in a single metal or alloy. Well-designed engineering components open up opportunities for material combinations of composites that are lighter, stronger, stiffer and therefore more useful at high temperatures. Many composites show good promise to meet the demanding requirements against environmental attacks. Current and projected needs of the Navy for composites are manifold; they range from radomes, IR-uses, structural members for low and high temperature turbine and compressor units, deep submergence uses, lasing materials to special coatings for antiradar purposes, electronic substrates, body armor, transparent armor, and a host of other naval ordnance needs.

The full potential of composites cannot be realized until the important parameters controlling the relationships between uniformity, processing variables, microstructure, mechanical strength, and deformation behavior are clearly delineated. Regardless of the choices involving material combinations, effects of the design of the composite microstructure and its fabrication must be understood to develop the desired properties.

The Navy's research program in this area is represented by many-sided activities, both by way of contracts and in house laboratory efforts. The Office of Naval Research has been supporting for several years selected research on composites. This research is fundamental in nature but oriented to support other work within the Navy and elsewhere. Composite research is incorporated into the Navy's Metals and Ceramics Research Program; its contributions are aimed at characterizing the nature of matrix material and of dispersoids, the interfacial bonding which affects strength and mechanical properties, and the interplay of processing variables. The combination of these factors, in turn, determines important properties of the composite, such as the deformation and fracture behavior of these unique materials. Even though astounding progress has been achieved at many research sites, there remain many unanswered questions. To cite but one important example, fatigue characteristics, such as response of composites to alternating stresses, are virtually unknown.

The program at Stanford University, one of several ONR sponsored programs in this area, deals with the preparation and examination of "particulate" composites to achieve an understanding of the mechanical behavior of such materials under various conditions of temperature and rate of deformation. The objective is to find a scientific-technological rationale to achieve acceptable mechanical strength properties in composites for critical and elevated temperature or environmental applications. The article describes two main types of composites, "fiber or whisker reinforced" composites and "particulate" composites, studied at Stanford University. The unfolding of exciting possibilities for the future of composite materials based on such research are clearly indicated.

W. G. Rauch
Office of Naval Research

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There is currently considerable interest by our leading research institutes, universities, and technical industries in the understanding and preparation of materials called composites. Consisting of mixtures of two or more dissimilar materials, composites have great promise as structural materials. The reason is that the combined properties of each component can lead to a composite body which is far more useful for a particular application than may be achieved if each component were used singly. An example is tungsten infiltrated with silver. Prepared by powder metallurgy methods, this material was first used for arc resistant electrical contact devices and more recently as a heat resistant rocket nose cone material. In the latter case, the tungsten matrix material maintains structural integrity even when exposed to temperatures exceeding 5000°F because of evaporation-cooling of the silver as the composite is heated above the boiling point of silver. A photomicrograph of such a composite is shown in Figure 1.

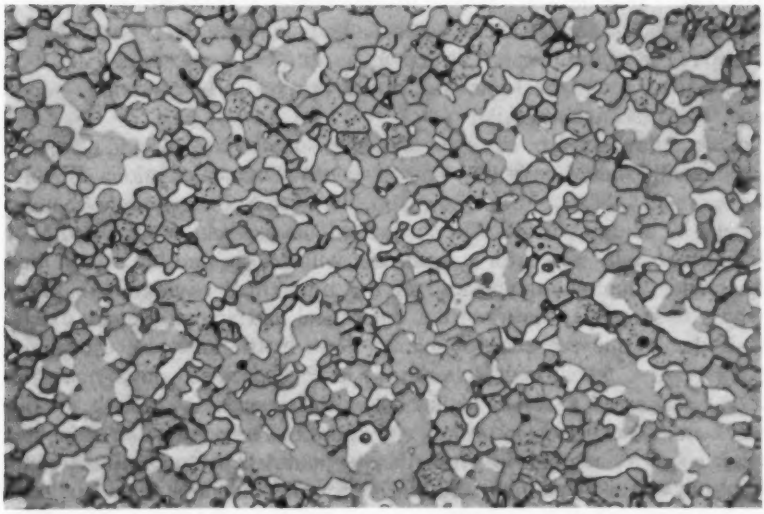

Figure 1 — Photomicrograph of silver infiltrated tungsten showing occasional uninfiltrated pores (small dark areas) in tungsten matrix. The light regions are silver and the gray regions are tungsten. Magnification is 500X. Murakami's etching reagent used.

At Stanford, the Office of Naval Research is sponsoring research on composite materials. Our emphasis has been to understand the contribution of each of the two components in a binary composite to the resulting mechanical properties. Our experimental results suggest many possibilities in the application of composite materials to technology.

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Before we proceed to describe this research we will give a short description of the background information which indicates the ultimate possibilities available to the "mechanical" materials scientist in the preparation of exciting new structural material. This background will then be used to indicate the potential of using "composites" in future structural applications. Our own observations in this field will be emphasized.

Ultimate Goals of the Mechanical Scientists

The availability of suitable materials very often imposes the practical limitations on the performance of engineering structures and devices. For example, improved jet engines for aircraft will depend upon the development of higher strength to weight ratio and higher temperature resistant turbine materials than are now available. Improvements in air frames and particularly the construction of future space vehicles require that new, lighter, high strength, high elastic modulus, structural materials be used. These are only two of the challenges that the future poses for the materials scientist. In order to understand how these demands for improved structural materials are to be fulfilled, some things must be understood about the basic mechanical properties of crystalline solids and their resistance to failure.

Calculations of the strength of perfect metal crystals indicate that pure metals should have very high strengths. Such calculations indicate, for example, that a rod of pure iron, one square inch in cross-section, should be able to withstand about *two million pounds* in tension without failing. Actually pure iron is weak and will deform and break at a load no higher than one-thousandth of the theoretical strength. We know why a descrepancy between the theoretical and actual strength exists. It is due to the presence of minute flaws in the lattice of crystalline solids. These flaws or defects, known as dislocations, move when the metal is stressed at low loads far below the theoretical strength, greatly weakening the resistance to flow and fracture. The material scientist and engineer seeks methods for strengthening materials by making it more difficult for the dislocations to move. One way this might be done would be to prepare a perfect crystalline material that is dislocation-free. This has been done on a small scale in the form of ultra fine, short filaments called "whiskers." So far, these specially grown "whiskers" approach the theoretical strength only when they have dimensions that are about one ten-thousandth of an inch in cross-section. It appears unlikely that ultra strong dislocation free material in massive form will be achieved, especially with the presently used metalic elements. It is for this reason, among others, that much research an development has been initiated in the direction of embedding these strong, fine "whiskers" or "fibers" into a relatively soft and weak matrix material. The resulting composite can be very strong indeed and there are now reliable theoretical methods

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for predicting the "elastic" and "plastic" strengths of such composites as influenced by the amount of second hard phase and by its distribution.

Two Major Types of Composites

In the following sections, we will describe the two basic types of composites that have received considerable attention and the merits of each. One type of composite is known as the "fiber reinforced" (or "whisker" reinforced) type composite. Here fibers or whiskers are usually embeded in a specific direction in a given matrix material. A photomicrograph of aluminum strengthened by boron fibers is shown in Figure 2a. Another type of composite is known as the "particulate" composite. Here the hard component is present in the form of fine particles (usually in the order of one one-hundred thousandth of an inch) to a given matrix material. The majority of high strength alloys intended for structural applications in the most general sense could be classified as particulate composites. However, alloys that rely on a solution heat treatment and precipitation process are not usually termed "composites" but are generally called "precipitation hardened" alloys. Nevertheless, the dividing line between the two types of materials is not sharp. As an example, iron containing fine particles of iron carbide, prepared by a combination of heat treatment and mechanical processing is difficult to classify; in terms of microstructural appearance, however, it would certainly be classified as a "particulate" composite as can be seen by the photomicrograph shown in Figure 2b.

Fiber Composites

"Fiber reinforced" composites are usually very strong when tested in the direction of orientation of the fibers. Their elastic strength (and often their breaking strength as well) follow the so-called additive law of mixtures. The predicted elastic strength (Young's modulus) is shown for a boron-aluminum fiber composite in Figure 3. It can be seen that a 50 volume percent boron-aluminum composite is characterized by a Young's modulus of 32×10^6 pounds per square inch when tested in the direction of the fiber. This elastic strength is even higher than that for steel (30 million psi) with a corresponding density of only one-third that of steel. When properly used, the technological possibilities for such a material are indeed very exciting. The main problem with fiber-metal or whisker-metal composites is that they are highly directional in their mechanical characteristics. Their elastic strengths follow the lower curve shown in the adjoining figure when tested at right angles to the fiber axis. Thus a 50 volume percent boron fiber would exhibit an elastic modulus of about 17×10^6 psi. This is still a respectably high elastic modulus for aluminum base alloys.

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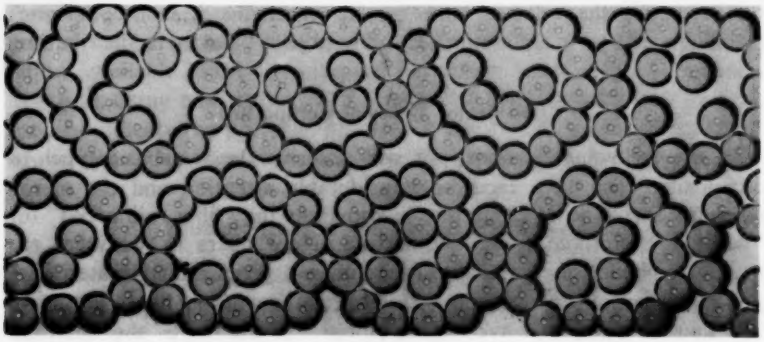

Figure 2a — Composite of aluminum containing boron fibers is an example of a "fiber-reinforced" composite. (Courtesy of Vidoz and Crossman, Lockheed Res. Lab. Palo Alto.) Magnification 50X.

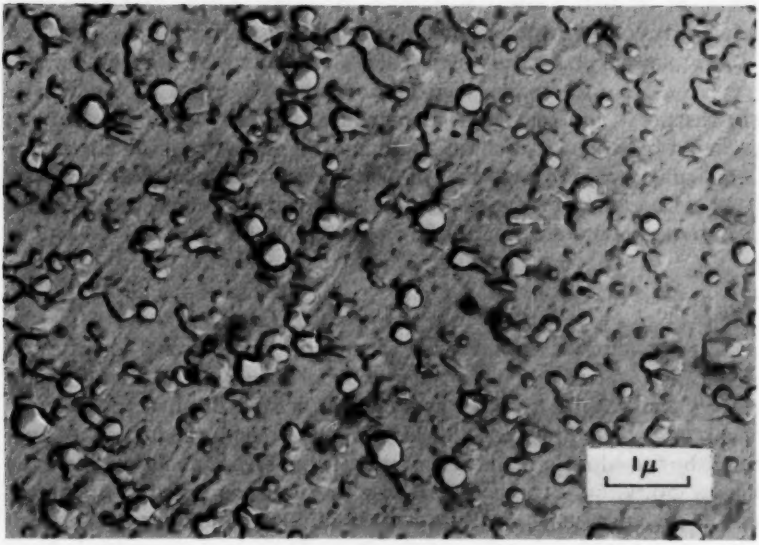

Figure 2b — Iron containing fine iron carbide particles can be considered as an example of a "particulate" composite. Magnification 15,000X.

The breaking strength, however, is very low and equal to about the strength of the weakest of the components involved, in this case aluminum. Even when such composites are tested at only ten degrees misorientation from the fiber axis, failure will occur at a relatively low stress due to shear between the matrix-fiber interface. The other major problem with fiber and whisker-metal composites (especially the latter)

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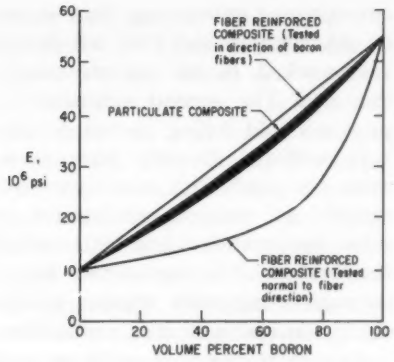

Figure 3 — Predicted elastic behavior of aluminum-boron alloys when in the form of "fiber" composites and "particulate" composites

is the extremely high cost of preparation of such materials. Nevertheless, it is expected that such materials will find application in future structural bodies and are worthy of further extensive fundamental and applied research. Currently, major emphasis is being placed on filament-metal composites where the filament are elastically strong and have yield strengths. Examples of such filaments are silicon carbide, sapphire, boron and graphite.

Particulate Composites

Research on particulate composites seems to have proceeded in one of two directions. Historically the first direction was toward cermets soon after the termination of World War II. Cermets are basically powder metallurgy products containing a large amount of hard second phase, typically over seventy percent by volume, with the remainder a soft metallic binder material. Usually the powders used were coarse. This activity contributed very little to the development of new technological materials because most of the cermets evaluated were too brittle. The second direction in research on particulate composites was towards development of fine particles of a second hard inert phase uniformly distributed in a metallic matrix. Such research has proved to be quite rewarding and TD Nickel (2 percent ThO_2 in Ni) can be considered a product typical of this approach. In general, the amount of the second hard phase added has been kept small (typically 2 to 3 percent). Such materials, however, often-times exhibit strong directionality in their mechanical properties because cold-working is generally relied on as a means of obtaining high strengths in such composites.

Through the Office of Naval Research sponsored program a new method of preparing dispersion hardened composites which results in non-directional mechanical properties has been developed. This method involves a combination of powder metallurgy techniques and mechanical

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comminution processing. That is, powders of the two components are mixed, sintered and then hot extruded. After extrusion the sample is cold worked, broken up into small chips, and then resintered and re-extruded. The second extrusion is performed at right angles to the previous cold rolling operation, and thus the microstructure becomes very uniform. Usually three such sintering-rolling-extrusion operations are used. Zinc-based composites prepared in this manner have resulted in isotropic mechanical properties, high tensile ductility at room temperatures, and high strengths compared to pure zinc at high temperature. The method we have developed for the preparation of isotropic composites appears to be unique and we believe that it is readily amenable to mass production methods.

As a result of our research on such composites we believe that a new direction of study of particulate composites has been opened. That is, it is possible that useful composites containing large amounts of a

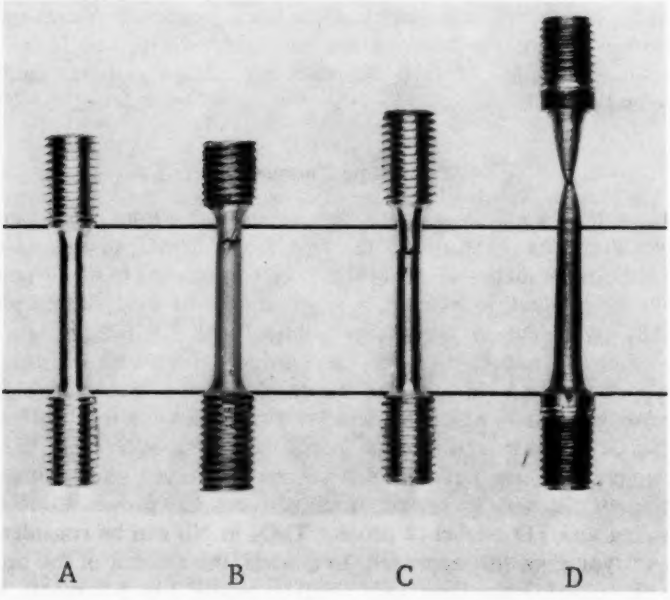

Figure 4 — Tensile bars of zinc containing various amounts of tungsten particles deformed at room temperature to failure. A and B depict undeformed and deformed pure zinc. C depicts zinc containing 5 volume percent tungsten particles. D depicts zinc containing 15 volume percent tungsten particles. When a small amount of tungsten particles are added to zinc, no increase in elongation is observed over that for pure zinc (compare C with B). When a large amount of tungsten particles are added, fifteen volume percent, the particulate composite becomes very ductile (specimen D).

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second hard phase in the form of a very fine particles can be prepared by the unique method developed in Stanford's ONR program. We believe that studies of particulate composites containing ten to fifty percent of a second hard phase, in the form of ultra fine particles, may well lead to the most interesting composites developed to date. As an example of the unusual influence of the presence of a large amount of second hard phase we have found that five volume percent of tungsten will not improve the ductility of zinc at room temperature, but fifteen volume percent tungsten increases the ductility of zinc extensively. This is dramatically depicted in Figure 4 showing zinc-tungsten samples elongated in tension at room temperature. The pure zinc and zinc-five percent tungsten samples fail after extending only about 20 percent with virtually no "necking" down of the sample. On the other hand, the fifteen volume percent tungsten in zinc material is shown to have high ductility as exhibited by the extensive "necking" occurring and by the high degree of uniform elongation before fracture occurred.

Such particulate composites as we have described appear very exciting from the viewpoint of elastic strength. For example, a particulate composite of aluminum containing fifty percent boron should have a Young's modulus of about 30 million psi (See Figure 3). This material would be elastically as strong as steel and should be elastically isotropic, a very important advantage over the fiber oriented composite. We believe the potential returns in terms of developing new structural materials appears very high with such unexplored composites.

New Concepts in the Physiological Response to Stress

A milestone in the annals of physiology occurred in the early 1900's when Hans Selye introduced proof that the stress-induced energy mobilization state is attained through an increase in the blood concentration of the catecholamine adrenalin, released by the adrenal gland. A present ONR contractor, Dr. J. D. Barchas at Stanford University, is studying the role of several catecholamines in stress and in fatigue. These substances are synthesized in the brain as well as in the adrenal. During fighting stress in rats, radiotracer assays showed a decreased brain utilization rate of nonadrenalin (chemically similar to adrenalin). When brain synthesis of another catecholamine, serotonin, was inhibited, however, the utilization of noradrenalin by the brain increased during fighting. A complex interaction of brain serotonin/noradrenalin also was seen to exist during fatigue/recovery. If catecholamine metabolism could be manipulated via drugs to alleviate fighting stress during combat and hasten recovery from fatigue, as Dr. Barchas plans, this research would be of great service to military personnel.

Another important finding in Dr. Barchas' investigations was a new loop in the well-known interrelationships of the brain and the adrenal in the body's reaction to stress. It has been accepted that brain ACTH carried by the blood to the adrenal stimulates release of adrenal steroids. Dr. Barchas has found that adrenal steroids affect utilization of brain catecholamines which in turn affect release of ACTH. Thus the picture emerges of a pivotal role of the brain catecholamines in enabling an organism to handle stresses effectively.

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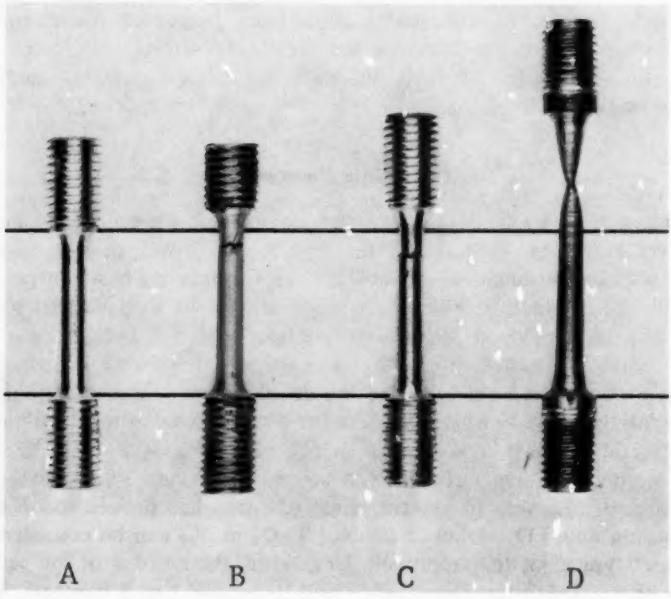

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Relevance and University Research

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The "crisis in research" will undoubtedly continue to occupy the attention of many people during the coming months as priorities are discussed, programs re-evaluated, and budgets scrutinized. Many of us in the Universities are deeply concerned about the potential consequences of these discussions. We are being forced to justify our interaction with the Department of Defense because many are urging us to turn our backs and shrug off the past twenty-odd years as an interesting experiment and look to the non-mission-oriented agencies for the complete support of research. But even if this is possible, we must ask whether we should encourage this direction for a national policy for the funding of research. Then there is the question of relevance and how this criterion is to be applied by the agencies in judging programs. It is clear that these are not unrelated issues.

If one considers the number and the size of the engineering schools in this country, one can only be impressed by the resources that are committed to the training of engineers and applied scientists. The significance of this very large investment in both effort and resources must be measured against the value of two principal benefits that this nation receives from its university research program, the pool of trained people and the results of the many research programs. In a more or less ideal situation one would expect the university faculty and their students to have a broad exposure to the applied problems whose solutions are of importance to society. But this presents an interesting dilemma to the universities, for they do not normally generate those problems that require the engineering of new systems. Thus, the definition of the problem area, if you like the focus for the research, must be provided by outside agencies, such as society as a whole, the mission oriented agencies, or industries, all of which have urgent problems to solve. It is the contact with the world outside the university that provides this orientation and the sensitivity to needs. Whereas the merit of research in the fundamental sciences can be judged on abstract terms, research in the engineering and applied sciences must not only be "good," it must address an important problem. Thus the university research person in the applied sciences and engineering must look to activities outside his own environment. The mission agencies, of which the Department of Defense is a particular example, has a genuine contribution to make to this orientation of research.

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The critical issue to be discussed is not so much whether research will contribute to the solutions of the problems but rather the time frame in which the supporting agencies view this research and whether they believe that they can justify its relevance to their future problems. Although the numbers are not particularly critical here, it seems reasonable for the engineering and science *research program* to look ahead to problems that are about fifteen years in the future. A time less than ten years is unrealistic since about seven years are required to translate a research idea into use. The upper limit of about fifteen years is a limitation that is imposed by the rapid advance of technology whereby problems may simply be by-passed by whole new technologies that may evolve.

What then are the problems that will confront the Department of Defense in 1985 and what research is being done in the universities that will provide the basis for solving these problems? Many of the problems in 1985 will be the same, in name anyway, that exist in 1970. System design, protection against hostile environments, remote system operation, reliability, and communications will continue to be critical, just as they are today. How then, do we evaluate the relevance of our research in terms of providing the capability to handle these problems in 1985?

A key element in each of the areas mentioned above is control and this invariably will depend upon some type of computer. A number of critical problems must be solved before we can achieve subsequent generations of computers, and these are generally not solvable by a simple extrapolation of our present technology. Further miniaturization, a major improvement in reliability, and flexible interactive input-output will be required.

In miniaturization, consider that generation of computers beyond those which we envisage will be possible with LSI. The question is, how tightly can one really pack elements? What will be the properties of elements whose isolation is only a hundred Angstroms where quantum mechanical effects can dominate classical effects? How can these effects be utilized to provide interconnections where needed and isolation where desired? Can barrier heights to electronic tunneling be controlled in such a way that interconnections can be made or modified in an adaptive fashion? Can the properties of the surfaces be controlled in such a way that they can provide connections, not with evaporated films but with the material itself?

Future generations of computers may well depend upon quantum mechanical processes for their operation. The amount of research presently being done in these areas is pitifully small compared to what is needed if this is to come to pass.

Are there other ways of transferring signals in systems? What about using light? The bandwidth can be large, response fast, and cross-talk

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negligible if components can be spectrally tuned. High efficiency room temperature solid state lasers will be needed for sources. Can we fabricate large logic systems that are optically coupled? Can we really control spectral sensitivity of specific components? Optical coupling offers many interesting possibilities.

As the level of complexity of fabrication increases to include thousands of elements on one unit, the problem of reliability becomes more critical. The hardware system design must be carried out with a close interaction with the software system design. New techniques for logical design will be needed. Reliability and fault diagnostic procedures will have to be provided during the design stage and not after the fact. A capability for modifying the interconnection of elements will probably be needed to provide alternate paths if an isolated fault is to be prevented from disabling a unit. One needs only to consider the re-routing of signals in a biological system to appreciate how far we are from achieving adaptability for faults in present computer systems.

But smaller computers are far from a panacea for all ills. We have to be able to communicate with computers in a more natural language and not be limited by formal languages. We must learn how to organize and manipulate large masses of data, and how to interact with it. 10^{12} bits represents more than 10^7 pages of printed material. How do we economically encode such extensive data? Machine organization is also a key factor which is incompletely understood.

Increased demands will be placed upon computer memories. Randomly addressable, read and write memories of very high densities will be needed. Can we conceive of memories with 10^{12} bits/cm^2 capacities? Optical memories are capable of 10^8 bits/cm^2 and scanning electron beam memories of 10^{12} bits/cm^2. The former is realizable now. The latter requires extensive research, but since there is nothing that violates the laws of physics it has great promise. Holographic techniques offer still other possibilities for high density storage of information.

With such computers one has the possibility of controlling sophisticated systems in hostile environments—under the sea, on battlefields, in radiation fields, *etc.* Control requires feedback to a remote operator, it requires stability, it requires flexibility. Control theory is an active area of research now. It needs to be expanded and more extensively applied to such problems.

Simultaneous communications to large groups of people will be more essential as the movement of groups becomes more rapid and as response times become shorter. Large display devices of high resolution and low power consumption will be needed. The use of displays in command stations,in aircraft and even for the small combat group offers new possibilities for increasing flexibility and effectiveness. But new materials and processes are needed if this is to be realized. Inevitably, computers will be called upon to participate in this process.

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The communication of people to computers, of computers to machines, of people to people *via* computers and of people to machines *via* computers presents us with challenges whose solutions can influence the operation of every major organization in our society, civilian and military.

What are the directions of present research that will contribute to these problems? Surface physics and surface chemistry are areas which are now being explored with new sophistication. Catalysis and gas-surface interactions are beginning to be understood for the first time. Thin film systems, involving processes with films of tens of Angstroms thickness, offer possibilities of understanding the details of the interactions that occur between insulators, metals and semiconductors on the quantum mechanical level. Luminescent phenomena in semiconductors offer the possibility of new efficient light sources of a pre-determined spectral quality. A great deal of very fundamental research is still needed in these areas.

The diagnoses and reliability of computers must be treated in much greater detail if failure is not to result in disablement. Software reliability, in the sense of effective roll-back, must be provided if one is to prevent power failures or massive temporary failures, as in ionization fields, from permanently disabling the systems.

The discussion addresses a limited problem area, but one which appears to be large and critical for the Department of Defense and for many civilian organizations. We have to be prepared to solve these problems if we are to be ready for 1985. These and many similar problems are not going to be solved by a simple extension of todays technology. Research coupled with a genuine appreciation for it's "relevance" in developing new methodology and techniques which will be required to solve the future problems of society and the mission agencies is the only answer. So long as we have problems to be solved we have needs for research. Both the universities and the mission agencies can benefit from a continuing close interaction as they explore the problems of the future.

Cavitation Studies

For the first time an accurate theoretical analysis is available which follows the collapse of a spherical vapor cavity near a solid boundary. The calculations by M. S. Plesset and R. B. Chapman at the California Institute of Technology under ONR sponsorship show that a large deformation of the bubble takes place fairly early in the collapse history. A jet is formed directed toward the solid boundary. The jet impact on the boundary generates high stresses which lead to cavitation damage. The analysis includes such effects as instability of the cavity shape, and compressibility of the liquid and vapor. The results of this theory give a significant clarification of the mechanism for cavitation damage.

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Controlling Oil Pollution of Harbors Through Biological Means

With the exception of a few nuclear-powered vessels, all modern naval and merchant ships depend on oil for their fuel. Increasing amounts of this precious but messy commodity are being extracted by off-shore drilling rigs and transported in super-tankers across the oceans. Accidents, shipwrecks, or actions of war cause some of this oil to pollute the sea on a frequently annoying or sometimes even disastrous scale. Public outcry and government regulations have proven so far woefully inadequate to prevent such occurrences. Anticipated increases in shipping and in the use of ocean resources are likely to increase both the scale and the frequency of future oil pollution incidents.

The Navy has begun a research program aimed at better methods of controlling oil pollution of harbors and beaches. The study will focus on the decomposition of oil spill through natural processes, including "fertilizing" an oil slick the way plants are fertilized.

Polluting oil, being lighter than water, spreads out on the ocean surface forming a "slick." The more volatile components evaporate rapidly, the nonvolatile fractions are gradually dissipated by chemical, photochemical and biochemical degradation. Of these three processes, biodegradation of the oil is by far the most significant self-purification process active in the oceans. Oil serves as food for numerous microorganisms which, given time, dispose of it in a slow but sure manner. Oil slicks on the open sea are usually left to this natural degradation process. Though such slicks are destructive to sea birds, other marine life is not known to be seriously affected. The situation is different in coastal waters where, unfortunately, most of the major oil spills occur. Oil, if driven on shore by wind or currents, destroys the rich marine life of the tidal zone, prevents recreational use of the beaches and causes severe losses in both esthetic and economic terms.

The principal objective of the study, conducted by Rutgers University for the Office of Naval Research's microbiology program, is to find ways to speed up the process of biodegradation. The Navy is concerned with the possibility of an accident resulting in a ship spilling oil close to shore.

Currently used emergency measures designed to combat such oil slicks fall into three categories: physical removal, sinking, or dispersion. The first technique, unfortunately, is seldom feasible; the second and third merely render the oil less offensive, but do not eliminate it. The ultimate disposal depends on biodegradation.

Sinking of oil is induced by spreading heavy absorbents such as ground chalk or silicon-treated sand on the slick. The disadvantage of this technique is the gradual release of the oil from the absorbent. Lack of sufficient oxygen on the sea bottom tends to retard biodegradation. Dispersal of oil slicks by detergents is the method of choice in most situations, but occasionally, oil dispersants have caused more damage to marine life than the oil spill itself. New dispersants, supposedly less toxic to higher forms of marine life, are currently being field-tested. However, little attention has been paid to the question of how the ultimate biodegradation of oil is affected by dispersants. The increased surface of the

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Collection of samples for isolation of oil-degrading microorganisms from the polluted Arthur Kill (from left to right: Mr. M. Pirnik and Mr. R. Atlas, graduate students, and Dr. R. Bartha).

dispersed oil should favor microbial attack, but inhibition of microorganisms by some dispersants may more than counteract this effect. Furthermore, there is evidence that the scarcity of certain essential mineral nutrients in sea water limits the biodegradation rate of oil. The ideal dispersant should not only be harmless to oil-degrading microorganisms, but should supply these limiting nutrients. In addition, biodegradation might be accelerated by "seeding" such dispersants with cultures of efficient oil-degrading microorganisms.

Previous research at Rutgers demonstrated that the biodegradation process can be hastened by seeding the oil with mineral nutrients, particularly nitrogen and phosphorus, which promote the growth of microbes. One of the tasks of the current research is to find effective ways to "fertilize" oil slicks with these substances, which are notably scarce in oil and sea water. At the present time there is no known way to add these fertilizers because they dilute quickly in sea water.

The solution could be provided by using some "binder" material to hold the nutrients as the oil is seeded. This could be done in conjunction with a biodegradable chemical, which would break up the oil into smaller particles easier for the bacteria to attack.

Since oil, whether crude or refined, is a complex mixture containing various proportions of some 200 known compounds and many unknown ones, Rutgers

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scientists have formulated a basic "model petroleum" for their experiments. The model petroleum will be subjected to the action of several strains of bacteria under various conditions in laboratory situations to determine which are more effecient in promoting biodegradation. After extensive laboratory experiments, field tests will be conducted on the seashore and estuaries of New Jersey.

The research group at Rutgers University is seeking ways to limit oil pollution damage by such microbiological approaches. The four-year project entitled "Biodegradation of Oil Slicks in the Marine Environment" was initiated on January 1, 1970, and is headed by Dr. Richard Bartha.

Virus Autointerference

Autointerference by viruses is a phenomenon observed by virologists in which reduced multiplication of a virus occurs in hosts inoculated with large doses of virus. With viruses showing this phenomenon maximum yields of virus are obtained when the host is inoculated with lower doses of virus. At the Naval Biological Laboratory, Oakland, California, a study of the nature of this phenomenon was made by Dr. Neylan A. Vedros in order to learn the basis for the interference.

With the use of one of the Rhabdoviruses (viruses which are rod-shaped) an examination of particle size and morphology of several virus preparations, revealed that a normal suspension of virus contains two kinds of particles: a regular bullet-shaped structure (L) about 200 millimicrons in length and a smaller rod-like particle (S), about one-third the length of the L structure. When the two particles were separated, it was found that the L particles constituted the infectious virus which multiplied with high yield of progeny, and that the S particle is unable to produce progeny. It was also seen that the progeny of the L particles consisted of both L and S particles. The S particles were demonstrated as inhibitors of infection of cells by the L structures. The action of the interfering S particles on susceptible host cells has not been determined.

Since rabies virus is a member of the Rhabdovirus group there is hope that information gained in extensions of the above study would throw light on means to inhibit growth of rabies and virus and thus protect individuals who may be bitten by rabid dogs.

The phenomenon of viral autointerference has also been described with influenza virus, and some scientists are of the opinion that this phenomenon may also occur with other viruses. Research to learn the mode of action of autointerference by these viruses may provide new tools for prevention and control of viral diseases in Navy and Marine Corps personnel.

Amorphous Semiconductor Mobility Gap Derived

Professor M. H. Cohen at the University of Chicago recently reported that he and postdoctoral fellow, Dr. E. Economu, had completed a rigorous derivation for the mobility gap in semiconductors. Because disordered materials can properly have no forbidden energy bands or *energy* gaps (where the allowed density of electrons is zero), Cohen postulated at the meeting of the American Physical Society the existence of a *mobility* gap, where for certain energies the mobility rather than the carrier density falls to zero. This model has been extremely useful in treating the mass of uncoordinated data on amorphous materials (materials made popular about a year ago by Mr. S. R. Ovshinsky) and has been widely applied. Until now, however, its theoretical validity had not been established.

XUM

Research Notes

Possible Causes of Decompression Sickness Described

Naval divers ascending from depths (or aviators ascending to altitude) too rapidly experience a change from high to low pressure in which the gas dissolved in the body fluids comes out of solution in the form of bubbles in the blood or tissues. These bubbles cause disorders in the nervous, circulatory, and/or respiratory systems in varying degrees of severity depending on the rate of decompression and the body state of the diver. Symptoms range from pain in the extremities to convulsions, rupture of blood vessels, difficulty in breathing. Death may result.

Until the early 1950's, the whole pathology of "bends" or decompression sickness was attributed to nitrogen bubble formation. However, since the onset of symptoms may frequently occur hours after decompression, there appeared to be more to the etiological development of bends than gas nucleation. In numerous postmortem cases of decompression sickness, fat emboli were found in the lungs. Obesity, type of diet, and fatty livers were hypothesized to be predisposing factors to decompression sickness.

An ONR contractor, Dr. A. T. K. Cockett from the University of Rochester, has constructed an etiological picture of the development of decompression sickness based on the similarities of the clinical symptomology of fat embolism and shock to that seen in decompression sickness. Dr. Cockett believes that nitrogen bubbles injure the liver such that it releases unstable lipids (fats) which may form emboli. The sludging of red blood cells, sequential to the presence of lipids and bubbles in the blood, initiate a shock reaction. Dr. Cockett uses heparin to break down lipids accumulating into fat emboli. Shock is prevented by expanding the plasma volume with dextran. Dextran also helps prevent the chemical reactions leading to blood clots. Dr. Cockett has also designed and used a radioisotopic lung scanning device for localizing fat and gas emboli in the lungs. These methods have been successful in alleviating decompression sickness in dogs, monkeys, and humans.

Linar, a New Word

A group of collaborating radio astronomers from the Massachusetts Institute of Technology and the U.S. Naval Research Laboratory Monday reported new upper limits for the angular sizes of several water vapor clouds located in regions of galactic space where new stars are believed to be in the process of formation.

The new data was obtained by a technique called "very long baseline interferometry" (VLBI) in which paired radio telescopes separated by up to hundreds of miles are focused on the same celestial object at precisely the same time. The VLBI technique effectively builds a radio telescope with a diameter equal to the distance between the two units and makes possible resolution of extraordinarily tiny objects. The resolution achieved by the M.I.T./NRL scientists, for example, was equivalent to an observer in New York telling the difference between a penny and a dime suspended over Fargo. N.D.

In the course of reporting their new measurements at a technical meeting at the National Radio Observatory here, the M.I.T. and NRL scientists introduced a new work into the vocabulary of radio astronomy and suggested a new and practical application for the VLBI technique.

The new word is "linar," which combines "line" and "star" in the same word-making fashion that produced the earlier radio astronomy terms pulsar and quasar. The group suggested linar as a descriptive term for point sources in the sky, like water vapor clouds, that emit radiation at specific wavelengths and thus show up as narrow lines on spectral charts.

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The new application for VLBI is in precision navigation and geodesy. The water vapor linars appear intense, or "bright," enough, the scientists said, that ships might one day be able to use them to obtain navigational position fixes during the day or night under all weather conditions. Ships could carry small telescopes, they said, which could be linked with a large land-based telescope *via* satellite. The idea of navigating by radio stars, they said, might be particularly useful in Antarctica where conventional methods are often unsatisfactory due to weather.

The importance radio astronomers attach to having increasingly exact data on the sizes of water vapor clouds and on their proximity to clouds of other kinds of intragalactic matter cannot be overstated. The business of radio astronomy is to receive and sift through the cacaphony of radio noises that whistle past the earth from space and, from these, to try to determine the nature of matter and the mechanisms of energy generation that underlie the physical universe.

The once-popular notion that space is an endless and empty void dotted here and there by visible planets and stars has been progressively debunked in recent years by what radio astronomers have been finding. Vast galactic regions apparently are filled with colossal clouds of gases. Complicated physical processes apparently are occuring in these clouds. For example, maser effects appear to be present, amplifying the intensity of radio radiation many billions of times in specific regional concentrations within the clouds. These specific regions of concentration are the class of sources that the M.I.T. and NRL astronomers suggest be called linars. It is likely that in some of these regions the radiative processes are evidence of stars being formed.

The presence of water vapor clouds in intragalactic space has been known for only a little more than a year. They are identified by their emission of radiation at wavelength of 1.35 centimeters, the wavelength which is characteristic for water molecules when in an excited state.

There are on the order of two dozen or so known water vapor sources in the sky, and, in general, they are closely associated with what are called OH sources, regions that emit radiation at 18 centimeters, the wavelength associated with clouds of hydrogen-oxygen molecules. The supposition is that these narrow line radiations associated with OH and water are the amplified results of intragalactic maser mechanisms.

Original measurements on water vapor clouds were made using single radio telescopes. The water source, however, could be specified only generally as to size and location and many tended to blend in with their associated OH radiation.

The VLBI techniques were applied by scientists representing the M.I.T. Research Laboratory of Electronics in Cambridge, Mass.; the M.I.T. Lincoln Laboratory at Lexington, Mass.; and the NRL's E. O. Hulburt Center for Space Research at Washington, D.C. The astronomers included B. F. Burke, D. C. Papa, G. D. Papadopulous, and P. R. Schwartz of the RLE staff, S. H. Knowles and W. T. Sullivan of NRL; and M. L. Meeks and J. M. Moran of Lincoln Laboratory. Data processing was performed at Lincholn's Haystack Facility.

Two sets of observations were carried out. The first, in December, 1969, employed the NRL 85-foot antenna at Maryland Point, Md., in tandem with the 140-foot NRAO antenna at Green Bank, W. Va., 141 miles away. The second, in January, 1970, linked the Maryland Point antenna with the 110-foot antenna at Lincoln Laboratory's Haystack Facility at Tyngsboro, Mass., a baseline of 451 miles.

The measurements focused on water vapor sources in four separate regions, all also associated with OH emissions.

One target was the radio constellation known as W49 which is located some 45,000 light years from the solar system. In W49, the M.I.T./NRL group measured five separate water vapor linars, each no more than three thousandths of an arc second in angular diameter. At that great distance, the clouds would have a linear feature size no greater than 40 times the distance from the earth to the sun. The OH linar in that region is known to be no greater than five hundredths of an arc second in diameter.

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A second target was in the Orion constellation about 1,500 light years away. Two water vapor linars were measured here with the same angular size of .003 arc seconds, which, at the much shorter distance, means they are no more than one and half times the earth-sun distance across. The associated Orion OH source is no more than 10 arc seconds.

Single water vapor linars were measured in the W3 radio portion of the constellation Cassiopeia and in the constellation Canis Majoris.

In W3, the water vapor linar measured to an upper limit of .01 arc seconds in angular size. Since it is about 6,000 light years away, this means its linear size is about 24 earth-sun distances. It is in this region that the OH sources, through similar VLBI observations made earlier, were resolved into seven discrete spots with angular sizes ranging from .005 to .02 arc seconds. It was this data that initially suggested maser mechanisms in space.

In Canis Majoris, the water vapor linar measured at the most .004 arc seconds across, or the equivalent of two earth-sun distances based on its distance of 1,500 light years.

A curious aspect to the water vapor linars, the M.I.T./NRL group said, is that they appear to grow alternately bright and dim over a period of a few weeks.

"It's as though we are looking at a puppet show with a time delay of several thousand years," one of them said.

All data in the two sets of observations were correlated and analyzed at the M.I.T. Lincoln Laboratory using computer programs developed for VLBI applications by personnel at that laboratory. The Lincoln Laboratory work was supported by the U.S. Air Force and the National Science Foundation. The RLE work at M.I.T. was supported by the NSF, the National Aeronautics and Space Administration and the Joint Services Electronics Program.

Project in Computer Language Conversion

Navy concern with achieving machine (computer) independence for Business Oriented Logistics applications has resulted in ONR establishing an experimental project with the Applied Logic Corporation, Princeton, New Jersey. This project has the objective of evaluating the relative efficiency of alternative available techniques for converting from a diversity of machine dependent languages to a standardized COBOL language. Particular attention is being paid to the potential of interactive programming for realizing the stated objective; interactive programming defined as a technique, operating in a real-time environment, which permits the programmer to interact directly with the system during the program production processes of composition, editing, debugging, compilation, execution, testing, and documentation. Six subjects or programmers are participating in the project; three from the Navy Fleet Material Support Office in Mechanicsburg, Pennsylvania and three supplied by the contractor. An extensive data base for the experiment was provided by the Fleet Material Support Office. The data base consists of documentation flow charts, and programs written in a machine dependent language. Progress to date includes design of the experiment, acquisition of the sample data base, specification of relevant conversion techniques to be included in the evaluation, establishment of controls, and development of measures of cost and effectiveness. All subjects completed a COBOL training course in February; actual program conversion in consonance with experimental design rules and measures was initiated in March 1970. The experiment is scheduled for completion during the current calendar year. This project has the concern of influencing Navy Department decisions on language conversion by providing technically sound information on: (1) relative efficiency of alternative conversion techniques, (2) feasibility and costs of conversion, (3) human factors considerations. The experiment has the active interest and participation of the Special Assistant to the Secretary of the Navy (SASN).

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On the Naval Research Reserve

Promotion Selections

There were nine hundred thirty-seven officers selected for promotion to Commander by the Fiscal Year 1970 Reserve Selection Board. Twenty-five were members of the Research Reserve Program:

	NRRC		*NRRC*
Allen, Craig R.	11-5	Jones, William P.	12-3
Bader, John P., Jr.	3-4	Kelly, Edward J.	9-1
Baker, Robert P.	8-7	Koch, Ulrich H.	12-5
Bloom, Thomas E.	12-2	Mann, Lawry W.	8-9
Cleary, William A., Jr.	5-8	McLean, Charles R.	4-7
Clegg, Ambrose A., Jr.	13-1	Morrison, Robert L.	3-14
Coleman, Charles N., II	8-4	Redford, John L.	6-3
Furlan, Allen J.	5-10	Reem, Glen M., II	1-1
Gerdon, Paul J.	5-8	Sampson, John L.	1-1
Haskins, John W.	4-4	Scott, Alfred L.	5-8
Hawkins, Charles W., Jr.	6-18	Vande Kieft, Lawrence J.	5-4
Johnson, Marion	4-1	Wicks, Franklin D.	8-13
		Wilcox, Richard H.	5-9

Eleven of the officers selected were from the new field and fourteen from the old. Other statistics based on the records of the Research Reservists selected for promotion are:

Year of Birth	*Date of Rank*	*Designator*
Earliest 1925	Earliest 7-1-60	1105:12 1355:2
Latest 1934	Latest 8-1-65	1405:9 1515:1 1615:1

Two thousand ninety six officers were selected for promotion to Lieutenant Commander. Fifty-five were members of the Research Reserve Program.

	NRRC		*NRRC*
Alden, David G.	9-6	Burthe, Jack H.	11-9
Allison, James P.	9-25	Cameron, Alan G.	1-1
Austraw, James D.	9-21	Canon, Leo J.	5-4
Barber, Ronald C.	13-4	Coates, John, Jr.	5-8
Berlandi, Francis J.	9-7	Cortelyou, Robert J.	12-6
Brainard, Robert B.	9-7	Dearth, Andrew H.	1-1

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	NRRC
DeBoer, Kenneth F.	9-5
DeLacy, Thomas J.	11-5
Dennison, Thomas W.	5-8
Foster, John W.	3-16
Galles, Harry L.	12-2
Goad, Tommy W.	11-5
Groves, Morton D. P.	12-3
Harmon, William R.	4-11
Helbron, John W.	9-21
Holveck, Arthur J.	4-5
Hopkins, David F.	3-4
Howell, David B.	3-16
Hunsberger, Harvey W.	9-10
Johnson, Pierce, Jr.	9-8
Kennedy, William J., Jr.	5-2
Knowles, Charles E.	8-3
Kusse, Bruce R.	1-1
Lemmer, George H.	8-4
Machen, Donald R.	8-9
Malecki, Gerald S.	5-8
Massey, Dale A.	9-23
McAneny, Colin C.	12-2
Mesloh, Raymond E.	4-7
Miller, Allen I.	4-3
Oberle, William J.	3-14
O'Donnell, William H.	4-1
Reid, Charles P. P.	9-12
Rowe, Raymond A.	11-5
Schneider, William J.	3-9
Sheridan, Earl A.	12-9
Slater, John W., III	6-6
Smith, Fred B., Jr.	9-5
Stone, Philip L.	9-2
Thompson, James J.	9-7
Thorp, Chester A., Jr.	12-3
Varner, John W., Jr.	6-6
Vohs, Paul A.	13-5
White, Raymond D.	6-18
Wilson, Larry K.	6-18
Wolcott, Norman M.	5-10
Wundrack, William A.	9-8
Young, George C.	4-11
Zumwalt, Crane E.	12-4

Statistics based on the records of the Research Reservists selected for promotion are as follows:

Year of Birth	*Date of Rank*	*Designator*
Earliest 1927	Earliest 3-1-56	1105:44 1315:2
Latest 1941	Latest 12-1-65	1355:2 1405:7

Selections to Captain and Commander were announced for officers in the Staff Corps. There were two officers selected in the Naval Reserve for Captain. These are as follows:

Medical Corps	*NRRC*
Spratt, John S., Jr.	9-28
Medical Service Corps	
Close, Perry	12-5

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Other officers selected in the Research Reserve were as follows:

Commander, Civil Engineer Corps

Long, Jimmy B.	9-5
Satterlee, Hugh M.	12-3

Commander, Medical Service Corps

Hargrave, Charles W.	5-10

Commander, Dental Corps

Ryan, James H.	9-26

Commander, Medical Corps

Amick, Lawrence D.	9-19

Superconducting Magnetic Sensor Development at Philco-Ford

The low temperature group at Philco Ford have successfully completed a two year ONR/ARPA supported research program on superconducting magnetometers and gradiometers. They have developed a stable niobium point-contact, rf-biased type of superconducting magnetometer which has operated reliably and reproducibly under repeated thermal cycling between room temperature and helium temperature (4 deg K). This group has operated portable instruments in a number of field tests under adverse conditions with good results. For example, operating in a deep mine shaft, they have easily detected 60 Hz magnetic fields from electrical equipment cables on the surface 450 feet above. On other tests, at an isolated desert location, the magnetic fields of high voltage power lines half a mile away (of the order of 10^{-7} gauss) were clearly detected. Most recently, the sensor (used as both a magnetic field meter and gradiometer) measured the minute magnetic fields associated with the electrical activity of the human heart.

New Device Shows Laser Action and Light Detection

Laser emission and photovoltaic infrared detection were reported for a new solid state device by K. W. Nill and coworkers at the Conference on Semimetals and Narrow-Gap Semiconductors in Dallas. The work is under the direction of Professor R. H. Rediker of MIT and is cosponsored by the ONR Physics Program. The device consists of a layer of metal evaporated on a specially prepared slice of a narrow-gap semiconductor alloy of PbTe and SnTe. The electron energy barrier created at the metal-semiconductor interface (Schottky barrier) gives the device some of the properties of a semiconductor p-n junction, but this new barrier is much easier to make and control. The device is thus basically different from semiconductor lasers and detectors made up till now, which have utilized p-n junctions for their action. Participation in this program by Lincoln Laboratory, after they had abandoned their narrow-gap detector work in 1968, indicates the interest in the device and the possibility it offers for a new improved approach to infrared detectors.

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Application of Stylistic Analysis Program

The University of North Carolina is developing a computer programming system which will produce stylistic analysis of verbal or written information. One of the directions within the task is to explore language content (and, concomitantly, the word choice and vocabulary dimensions of the user) by determining certain occurrence patterns of semantically-related words. This is being done with their VIA (Verbally-Indexed Association) developed computer programs which is currently being used by numerous researchers.

The purpose of this computer-aided research is to characterize as completely as possible the language usage of an individual, a group of individuals, an organization or institution, a region, a nation, or a group of nations, as that usage appears in documents, memoranda and other writings. The ability to characterize usage, (herein defined as stylistic analysis), implies the implementation of measures which will permit both the recognition of norms and of variations from these norms. Among the many applications of this research is its relevance for intelligence work concerned with the analysis of language for content/meaning, for indications of shifts in attitudes or assignment of priorities, for indications of a change in writer or speaker, and for the detection of any other linguistic clues to the behavior, or intended behavior, of an individual, group of individuals, or country in which the United States has an interest. The approach is to obtain the goal of automatic stylistic analysis in the development of a system of dynamically interactive computer programs which will reveal the linguistic pattern of texts and/or portions of texts.

The previously described VIA program is sufficiently advanced so that it is useful to researchers at other universities. The most recent user is Ohio State's Mershon Center for Education in National Security. Because the requests for the VIA package are becoming more numerous, and consuming too much of the Principal Investigator's time, a copy of the current VIA program package has been placed in the custody of the Institute for Social Science Research at the University of North Carolina. The Institute has the staff and facilities to supply copies on tape or cards, at costs, to any future requester. Also, whenever the program package is expanded or modified, a revised copy will be furnished.

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